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Research and Development for X-Ray Optics and Diagnostics on the Linac Coherent Light Source (LCLS)

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Abstract

The Linac Coherent Light Source (LCLS) is a 1.5 to 15 Å wavelength Free-Electron Laser (FEL), under development at the Stanford Linear Accelerator Center (SLAC). The photon output consists of high brightness, transversely coherent pulses with duration < 300 fs, together with a broad spontaneous spectrum. The output energy density per unit area, pulse duration, repetition rate, and small FEL spot size pose special challenges for optical components and diagnostics downstream of the undulator. Planning for the photon beam transport, manipulation and diagnostics downstream of the undulator has begun.

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1. Introduction

The LCLS photon transport system will transport FEL and spontaneous photons from the Undulator exit to the end of the last experimental Hall along a single, unobstructed, vacuum-tight flight path approximately 380 m long. Experimental and diagnostic equipment will be installed within tanks on motorized platforms so that they can be moved and out of the beam.

2. Layout.

In the conceptual design, Fig. 1, a Front End Enclosure (FEE) in the tunnel just downstream of the undulator houses optics and diagnostics common to

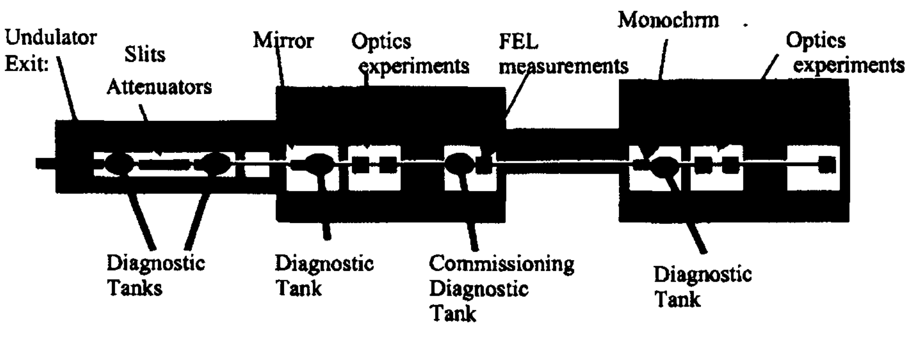

Fig. 1. Layout of LCLS photon transport, optics, and diagnostics systems.

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the experiments downstream.

The first experimental Hall, A, begins 40 meters from the undulator exit. This Hall, close to the undulator exit, is intended for experiments in atomic and plasma physics, as well as experiments on the basic physics of the FEL. The first ~13 m long hutch in Hall A contains a low-energy mirror system for removing high order harmonics from the low-energy (0.8 KeV) beam and a tank of diagnostics for monitoring the characteristics of the FEL beam entering the Hall. The second hutch has two large tanks containing x-ray optics for doing experiments requiring the focused beam. FEL measurements and experiments will be done the last hutch of Hall A.

Hall B, which begins 322 m from the undulator exit, has a similar layout, but is targeted for experiments in chemistry and biology. A 220 m tunnel connects the two halls.

3. Damage

Of primary concern are the damage thresholds for optics and other instruments placed in the beam. For a given FEL fluence, the actual dose delivered to an object depends on its distance from the undulator, the FEL photon energy, and the Z of its materials. The

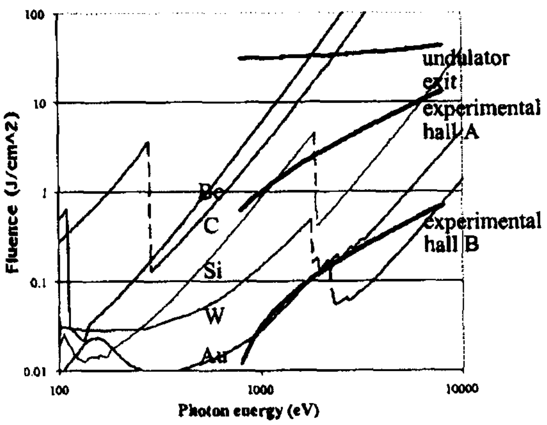

Fig. 2. X-Ray fluence required to melt selected elements at normal incidence vs. photon energy.

fluence required to melt a material is certainly an upper limit on its damage threshold. Figure 2, shows the fluence required, at normal incidence, to melt selected elements vs. photon energy compared to the expected (unfocused) FEL fluence in the experimental Halls. At the undulator exit Be and C, will not melt for photon energies above a few KeV. Be and C won't melt at any energy in Hall A, while Si will melt at lower energies. In Hall B, Si and W will not melt at normal incidence. Factors of ~100 in survivable dose can be obtained by operating mirrors at grazing incidence allowing higher Z mirrors to be used near the undulator exit and in Hall A.

4. Optics

The planned optical elements include slits, attenuators, focusing elements, a monochromator, a pulse width and delay system, and a low-energy mirror. The slits, intended to mask the spontaneous radiation and let the FEL beam through, are actually crossed pairs of grazing incidence mirrors in order to avoid damage if accidentally struck by the FEL. The attenuator is a windowless, differentially-pumped, gas cell for attenuating the beam at all photon energies for alignment purposes or for experiments requiring lower fluence. Both K-B and low Z refractive optical systems will be designed for experiments requiring a focused beam.

5. Diagnostics

The diagnostic tanks in the FEE, and in the front hutches of the experimental Halls, contain Facility Diagnostics, intended to be as nonintrusive as possible, to allow for pulse-to-pulse characterization of the FEL pulse energy, centroid, and spatial distributions. At high LCLS photon energies (8.26 KeV) the beam can be monitored by reflecting a small amount off of a very thin transmissive Be foil. At low photon energies we are considering a windowless, differentially pumped, ion/drift chamber system to provide pulse-to-pulse measurements of the beam's spatial moments and pulse energy.

Intrusive Commissioning Diagnostics for measuring spectra, pulse length, coherence, and pulse energy will be located in the commissioning Diagnostics tank.

6. Acknowledgments

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